skilled in the art while still coming within the penumbra of the subject invention.

Although specific features of the invention are shown in some drawings and not in others, this is for convenience only as each feature may be combined with any or all of the other features in accordance with the invention. The words "including", "comprising", "having", and "with" as used herein are to be interpreted broadly and comprehensively and are not limited to any physical interconnection. Moreover, any embodiments disclosed in the subject application are not to be taken as the only possible embodiments. Other embodiments will occur to those skilled in the art and are within the following claims:

What is claimed is:

1. An integrated inertial stellar attitude sensor for an aerospace vehicle comprising:

a star camera system;

a gyroscope system;

a controller system for synchronously integrating an output of said star camera system and an output of said gyroscope system into a stream of data; and

a flight computer responsive to said stream of data for determining from the star camera system output and the gyroscope system output the attitude of the aerospace vehicle.

2. The integrated inertial stellar attitude sensor of claim 1 in which the star camera system includes an active pixel sensor (APS) star camera for acquiring a star field image.

3. The integrated inertial stellar attitude sensor of claim 2 in which the star camera system includes a star camera analog-to-digital converter structured and arranged to convert the star field image to a digital representation of star location and intensity.

4. The integrated inertial stellar attitude sensor of claim 2 in which the gyroscope system includes a micro-electromechanical (MEMs) gyroscope system structured and arranged to acquire gyroscope angular rate data.

5. The integrated inertial stellar attitude sensor of claim 4 in which the gyroscope system includes a gyroscope analog-to-digital converter structured and arranged to convert the gyroscope angular rate data to a digital representation of gyroscope angular rate.

6. The integrated inertial stellar attitude sensor of claim 4 in which the stream of digital data is a digital data stream.

7. The integrated inertial stellar attitude sensor of claim 6 wherein the digital representation of the gyroscope angular rate includes gyroscope system reference, rate and temperature.

8. The integrated inertial stellar attitude sensor of claim 7 in which the MEMs gyroscope system is a three axis gyroscope system.

9. The integrated inertial stellar attitude sensor of claim 8 in which the MEMs gyroscope system includes a first axis sensor for sensing angular rate along a first axis.

10. The integrated inertial stellar attitude sensor of claim 9 in which the MEMs gyroscope system includes a second axis sensor for sensing angular rate along a second axis.

11. The integrated inertial stellar attitude sensor of claim 10 in which the MEMs gyroscope system includes a third axis sensor for sensing angular rate along a third axis.

12. The integrated inertial stellar attitude sensor of claim 11 in which the MEMs gyroscope system includes a first application specific integrated circuit (ASIC) associated with the first axis sensor for outputting a first signal.

13. The integrated inertial stellar attitude sensor of claim 12 in which the MEMs gyroscope system includes a second application specific integrated circuit (ASIC) associated with the second axis sensor for outputting a second signal.

14. The integrated inertial stellar attitude sensor of claim 13 in which the MEMs gyroscope system includes a third application specific integrated circuit (ASIC) associated with the third axis sensor for outputting a third signal.

15. The integrated inertial stellar attitude sensor of claim 14 in which the controller system includes a field programmable gate array.

16. The integrated inertial stellar attitude sensor of claim 15 in which the field programmable gate array includes a command circuit for selectively synchronously integrating the outputs of said gyroscope system and said star camera system in a predetermined pattern to isolate from each other each of their outputs during their

integrating.

17. The integrated inertial stellar attitude sensor of claim 16 in which the command circuit includes a programmable logic device for implementing said selective synchronous integration of the outputs of said gyroscope system and said star camera system in a predetermined pattern.

18. The integrated inertial stellar attitude sensor of claim 17 in which the command circuit includes at least one camera register for setting star camera rate of image acquisition and star camera power.

19. The integrated inertial stellar attitude sensor of claim 18 in which the command circuit includes a camera control device responsive to the camera register settings for controlling the star camera the camera.

20. The integrated inertial stellar attitude sensor of claim 18 in which the command circuit includes at least one gyroscope register for setting gyroscope power and a gyroscope reference.

21. The integrated inertial stellar attitude sensor of claim 18 in which the command circuit includes a gyroscope control device responsive to the gyroscope register settings for controlling the gyroscope.

22. The integrated inertial stellar attitude sensor of claim 21 in which the command circuit includes a data stream packer for interleaving the output of the star camera system and the output of the gyroscope system into the stream of data.

23. The integrated inertial stellar attitude sensor of claim 22 in which the gyroscope control device controls when the gyroscope system may receive gyroscope data.

24. The integrated inertial stellar attitude sensor of claim 23 in which the command circuit includes a power isolation and control circuit.

25. The integrated inertial stellar attitude sensor of claim 24 in which the power isolation and control circuit includes a power isolator for isolating star camera power from gyroscope power.

26. The integrated inertial stellar attitude sensor of claim 25 in which at least one gyroscope register sets when the power isolation circuit may receive a signal to transmit gyroscope power to the gyroscope system.

27. The integrated inertial stellar attitude sensor of claim 26 in which the flight computer includes a star camera system processor.

28. The integrated inertial stellar attitude sensor of claim 27 in which the star

camera system processor includes a camera memory for storing the star field image.

29. The integrated inertial stellar attitude sensor of claim 28 in which the star camera system processor includes an image processor.

30. The integrated inertial stellar attitude sensor of claim 29 in which the image processor includes a camera reader for reading the stored star field image.

31. The integrated inertial stellar attitude sensor of claim 30 in which the image processor includes a camera processor for generating star positions from the read star field image.

32. The integrated inertial stellar attitude sensor of claim 31 in which the image processor includes a star catalog.

33. The integrated inertial stellar attitude sensor of claim 32 in which the image processor includes a camera comparator for comparing the generated star positions to a star catalog.

34. The integrated inertial stellar attitude sensor of claim 33 in which the image processor includes a camera attitude generator responsive to an output from the camera comparator for generating a star camera attitude.

35. The integrated inertial stellar attitude sensor of claim 31 in which camera processor includes a converter for converting the attitude of the aerospace vehicle to an initial star position.

36. The integrated inertial stellar attitude sensor of claim 34 in which the flight computer includes a gyroscope system processor.

37. The integrated inertial stellar attitude sensor of claim 36 in which the gyroscope system processor includes a gyroscope memory for storing the gyroscope angular rate data.

38. The integrated inertial stellar attitude sensor of claim 37 in which the gyroscope system processor includes a gyroscope rate processor.

39. The integrated inertial stellar attitude sensor of claim 38 in which the gyroscope rate processor includes a gyroscope data reader for reading the stored gyroscope angular rate data.

40. The integrated inertial stellar attitude sensor of claim 39 in which the gyroscope rate processor includes a gyroscope compensator for processing gyroscope angular rate data and generating a compensated gyroscope rate.

41. The integrated inertial stellar attitude sensor of claim 40 in which the

gyroscope rate processor includes a gyroscope integrator for integrating the compensated gyroscope rate and generating a gyroscope attitude.

42. The integrated inertial stellar attitude sensor of claim 41 in which the flight computer further includes an attitude processor for receiving and processing the star camera attitude and the gyroscope attitude.

43. The integrated inertial stellar attitude sensor of claim 42 in which the attitude processor includes an aerospace vehicle attitude propagator for propagating the attitude of the aerospace vehicle.

44. The integrated inertial stellar attitude sensor of claim 43 in which the attitude processor provides the attitude of the aerospace vehicle in quaternion coordinates.

45. The integrated inertial stellar attitude sensor of claim 44 in which the attitude processor includes an error estimator for estimating aerospace vehicle attitude error.

46. The integrated inertial stellar attitude sensor of claim 45 in which the attitude propagator and the error estimator are implemented by a predictive filter.

47. The integrated inertial stellar attitude sensor of claim 46 in which the predictive filter is a Kalman Filter.

48. The integrated inertial stellar attitude sensor of claim 47 in which the Kalman Filter is a square root Kalman Filter.

49. The integrated inertial stellar attitude sensor of claim 47 in which the Kalman Filter is a 27 state Kalman Filter.

50. The integrated inertial stellar attitude sensor of claim 49 in which the attitude processor includes a gyroscope attitude gating device for preventing the attitude processor from receiving the gyroscope attitude upon power up of the integrated inertial stellar attitude sensor.

51. The integrated inertial stellar attitude sensor of claim 49 in which the flight computer includes a command control data interface.

52. The integrated inertial stellar attitude sensor of claim 51 in which the command control data interface includes a serial port for reformatting a signal representing the attitude of the aerospace vehicle and a signal representing the aerospace vehicle attitude error signal.

53. The integrated inertial stellar attitude sensor of claim 51 in which the command control data interface includes a counter for counting the number of times the attitude of the aerospace vehicle has been propagated.

54. The integrated inertial stellar attitude sensor of claim 53 in which the command control data interface includes a command processor for distributing commands based on command type.

55. The integrated inertial stellar attitude sensor of claim 54 in which the controller system includes an isolation circuit for isolating said stream of data from commands distributed by the command processor.

56. The integrated inertial stellar attitude sensor of claim 55 in which the flight computer further includes a self-scoring system to identify error trends in the aerospace vehicle attitude.

57. The integrated inertial stellar attitude sensor of claim 55 in which the self-scoring system includes an enabler for enabling the self-scoring system.

58. The integrated inertial stellar attitude sensor of claim 57 in which the enabler generates a self-score continuous frequency command to the command control data interface to increase the star camera rate of star field image acquisition to continuous frequency.

59. The integrated inertial stellar attitude sensor of claim 58 in which the self-scoring system includes a first comparator for comparing a continuous frequency star camera attitude over time with the attitude of the aerospace vehicle over time and

providing a self-score error output.

60. The integrated inertial stellar attitude sensor of claim 61 in which the self-scoring system includes a second comparator for comparing said self-score error output to a desired error threshold value and providing a threshold departure output.

61. The integrated inertial stellar attitude sensor of claim 60 in which the self-scoring system includes an error processor which outputs a self-score command to the command control data interface to increase the frequency of star field image acquisition.

62. The integrated inertial stellar attitude sensor of claim 61 in which the attitude processor further includes a star camera self-initializing device for providing the attitude of the aerospace vehicle to the image processor.

63. The integrated inertial stellar attitude sensor of claim 62 in which the attitude processor further includes a gyroscope self-initializing device for providing the star camera attitude to the aerospace vehicle attitude propagator.

64. The integrated inertial stellar attitude sensor of claim 1 in which the output of the star camera system is a star camera attitude.

65. The integrated inertial stellar attitude sensor of claim 1 in which the output of the gyroscope system is a gyroscope attitude.

66. An integrated inertial stellar attitude sensor for an aerospace vehicle comprising:

a star camera system;

a gyroscope system;

a controller system for synchronously integrating an attitude output of said star camera system and an attitude output of said gyroscope system into a stream of data; and

a flight computer responsive to said stream of data for determining from the star camera attitude output and the gyroscope system attitude output the attitude of the aerospace vehicle.

67. An inertial stellar attitude determination sensor for an aerospace vehicle comprising:

a star camera system including an active pixel sensor star camera;

a gyroscope system including a micro-electromechanical gyroscope;

a controller system for synchronously integrating an output of the active pixel sensor star camera and an output of the micro-electromechanical gyroscope into a stream of digital data; and

a flight computer responsive to said stream of digital data for determining from the active pixel sensor star camera output and the gyroscope output the attitude of the aerospace vehicle.

68. An inertial stellar attitude determination sensor for an aerospace vehicle comprising:

a star camera system including an active pixel sensor star camera;

a gyroscope system including a micro-electromechanical gyroscope; and

a controller system for synchronously integrating an output of the active pixel sensor star camera and an output of the gyroscope into a stream of data.

69. An inertial stellar attitude determination sensor for an aerospace vehicle comprising:

an active pixel sensor star camera;

a micro-electromechanical gyroscope integral with the active pixel sensor star camera;

a controller system integral with the active pixel sensor star camera and the micro-electromechanical gyroscope for synchronously integrating an attitude output of the active pixel sensor star camera and an attitude output of the gyroscope into a stream of data; and

a flight computer responsive to said stream of data for determining from the active pixel sensor star camera attitude output and the gyroscope attitude output the attitude of the aerospace vehicle.

70. An integrated inertial stellar attitude sensor for an aerospace vehicle comprising:

a star camera system;

a gyroscope system;

a controller system for synchronously integrating an output of said star camera system and an output of said gyroscope system into a stream of data;

a flight computer responsive to said stream of data for determining from the star camera output and the gyroscope output the attitude of the aerospace vehicle; and

a single housing disposed about the star camera system, the gyroscope system, the controller system and the flight computer.

71. An integrated inertial stellar attitude sensor for an aerospace vehicle comprising:

a star camera system;

a gyroscope system;

a controller system for synchronously integrating an output of said star camera system and an output of said gyroscope system into a stream of data; and

a single housing disposed about the star camera system, the gyroscope system, and the controller system.

72. A integrated inertial stellar attitude sensor for an aerospace vehicle comprising:

a camera/gyroscope assembly including:

a star camera system;

a gyroscope system; and

a controller system for synchronously integrating an output of said star camera system and an output of said gyroscope system into a stream of data; and

a flight computer responsive to said stream of data for determining from the star camera output and the gyroscope output the attitude of the aerospace vehicle.

73. The integrated inertial stellar attitude sensor of claim 72 including a first housing disposed about the camera/gyroscope assembly.

74. The integrated inertial stellar attitude sensor of claim 73 including a second housing disposed about the flight computer.

75. The integrated inertial stellar attitude sensor of claim 74 including a third housing disposed about the first and second housings.

76. An integrated inertial stellar attitude sensor for an aerospace vehicle comprising:

a star camera system;

a gyroscope system;

a controller system for synchronously integrating an output of said star camera system and an output of said gyroscope system into a stream of data;

a flight computer responsive to said stream of data for determining from the star camera output and the gyroscope output the attitude of the aerospace vehicle;

a first housing disposed about the star camera system and the gyroscope system;

a second housing disposed about the controller and the flight computer; and

a third housing disposed about the first and second housings.

77. An inertial stellar attitude determination sensor for an aerospace vehicle comprising:

an active pixel sensor (APS) star camera;

a micro-electromechanical (MEMs) gyroscope;

a controller system for synchronously integrating the output of the active pixel sensor (APS) star camera and the output of the micro-electromechanical (MEMs) gyroscope into a stream of data;

a flight computer responsive to said stream of data for determining from the active pixel sensor (APS) star camera output and the micro-electromechanical (MEMs) gyroscope output the attitude of the aerospace vehicle; and

a housing disposed about the active pixel sensor (APS) star camera and the micro-electromechanical (MEMs) gyroscope and the flight computer.

78. An integrated inertial stellar attitude sensor for an aerospace vehicle comprising:

a star camera system;

a gyroscope system;

a controller system for selectively synchronously integrating an output of said star camera system and an output of said gyroscope system in a predetermined pattern into a stream of data, said controller system including a command circuit for isolating from each other each of said star camera system output and said gyroscope system output during their integrating; and

a flight computer responsive to said stream of data for determining from the star camera output and the gyroscope output the attitude of the aerospace vehicle.

79. An integrated inertial stellar attitude sensor for an aerospace vehicle comprising:

a star camera system;

a gyroscope system;

a controller system for synchronously integrating an output of said star camera system and an output of said gyroscope system into a stream of data, said controller system including a data stream packer for interleaving said output of the star camera system and said output of the gyroscope system into the stream of data; and

a flight computer responsive to said stream of data for determining from the star camera output and the gyroscope output the attitude of the aerospace vehicle.

80. A self-initializing integrated inertial stellar attitude sensor for an aerospace vehicle comprising:

a star camera system;

a gyroscope system;

a controller system for synchronously integrating an output of said star camera system and an output of said gyroscope system into a stream of data; and

a flight computer responsive to said stream of data for determining from the star camera output and the gyroscope output the attitude of the aerospace vehicle, said flight computer including a star camera self-initializing device for self-initializing the star camera system with the attitude of the aerospace vehicle.

81. An integrated inertial stellar attitude sensor for an aerospace vehicle comprising:

a star camera system;

a gyroscope system;

a controller system for synchronously integrating an output of said star camera system and an output of said gyroscope system into a stream of data; and

a flight computer responsive to said stream of data for determining from the star camera output and the gyroscope output the attitude of the aerospace vehicle, the flight computer further including a self-scoring system to identify error trends in the aerospace vehicle attitude.

82. An integrated inertial stellar attitude sensor for an aerospace vehicle comprising:

a star camera system;

a gyroscope system; and

a controller system for synchronously integrating an output of said star camera system and an output of said gyroscope system into a stream of data adapted for input to a flight computer to determine the attitude of the aerospace vehicle.

83. A method of inertial stellar attitude sensing for an aerospace vehicle comprising:

acquiring an image of a star field output from a star camera system;

acquiring an angular rate output from a gyroscope system;

selectively, synchronously integrating in a predetermined pattern the image of a star field output and the gyroscope angular rate output into a stream of data;

converting the data representative of the star field to a star field image to determined the star camera attitude of the vehicle;

converting the data representative of the angular rate output to determined the gyroscope attitude of the vehicle; and

resolving the star camera attitude with the gyroscope attitude to generate an attitude of the aerospace vehicle.

84. The method of claim 83 in which said star camera system includes an active pixel sensor (APS) camera.

85. The method of claim 84 in which said gyroscope system includes a micro-electromechanical (MEMs) gyroscope system.

86. The method of claim 85 in which said gyroscope system is a three axis system.

87. The method of claim 86 in which including selectively synchronously

integrating the outputs of the gyroscope system and the star camera system in a predetermined pattern to isolate from each other each of the star camera system and gyroscope system outputs during their integrating.

88. The method of claim 87 in which resolving the star camera attitude with the gyroscope attitude includes submitting the star camera attitude and the gyroscope attitude to an attitude processor to obtain the aerospace vehicle attitude.

89. The method of claim 88 further including applying the attitude of the aerospace vehicle to self-initialize the star camera attitude.

90. The method of claim 89 further including applying the star camera attitude to self-initialize the gyroscope system attitude.

91. The method of claim 90 further including increasing the frequency of star field image acquisition to continuous frequency and determining continuous frequency attitude outputs over time, and comparing the attitude output of the aerospace vehicle over time to the continuous frequency attitude output over time to identify error trends in the aerospace vehicle attitude.

92. A method of inertial stellar attitude sensing for an aerospace vehicle comprising:

acquiring a star camera attitude from a star camera system;

acquiring a gyroscope attitude from a gyroscope system;

selectively, synchronously integrating in a predetermined pattern the star camera attitude and the gyroscope attitude into a stream of data; and

resolving the star camera attitude with the gyroscope attitude to generate an attitude for the aerospace vehicle.

93. A method of inertial stellar attitude sensing for an aerospace vehicle comprising:

acquiring an image of a star field output from a star camera system;

acquiring an angular rate output from a gyroscope system;

selectively, synchronously integrating in a predetermined pattern the image of a star field output and the angular rate output into a stream of data;

converting the data representative of the star field within the stream to a star field image to determine the star camera attitude of the vehicle;

converting the data representative of the angular rate within the stream to determine the gyroscope attitude of the vehicle;

resolving the star camera attitude with the gyroscope attitude to generate an attitude for the aerospace vehicle; and

increasing the frequency of star field image acquisition to continuous frequency and determining continuous frequency star camera attitude outputs over time, and comparing the attitude output of the aerospace vehicle over time to the continuous frequency attitude output of the star camera system over time to identify error trends in the aerospace vehicle attitude.

94. A method of inertial stellar attitude sensing for an aerospace vehicle comprising:

acquiring an image of a star field output from a star camera system;

acquiring an angular rate output from a gyroscope system;

selectively, synchronously integrating in a predetermined pattern the image of a star field and the gyroscope angular rate into a stream of data;

converting the data representative of the star filed within the stream to a star field image to determine the star camera attitude of the vehicle;

converting the data representative of the angular rate within the stream to determine the gyroscope attitude of the vehicle;

resolving the star camera attitude with the gyroscope attitude to generate an attitude for the aerospace vehicle; and

changing said predetermined pattern of selectively synchronously integrating.

95. A method of inertial stellar attitude sensing for an aerospace vehicle comprising:

acquiring an image of a star field from a star camera;

processing said image to provide a camera quaternion;

acquiring an angular rate output from a gyroscope;

processing said angular rate output to provide a gyroscope quaternion; and

resolving said gyroscope quaternion and said camera quaternion to provide an attitude quaternion for the aerospace vehicle.